Paper 5 Essentials

Time: 1 h 15m
Total: 30 marks

Always read and understand the questions first! In the question, find:

a. Aim or hypothesis
b. Independent variable
c. Dependent variable
d. Controlled variable

Skill	Total marks	Breakdown of marks	
Planning	15 marks	Defining the problem	5 marks
		Methods	10 marks
Analysis, conclusions and evaluation	15 marks	Dealing with data	8 marks
		Evaluation	4 marks
		Conclusions	3 marks

Defining the problem (~5m)

- Very basic questions like hypothesis, variables etc.

Planning an Experiment (~10m)

- Write in full sentences in pen
- Be as specific as possible
- You can number your steps, but you CANNOT write in point form
- Your methods need not be described in chronological order – as long as all points are there
- If involves drawing, then drawing must be done in pencil (rules for drawing applies)
- You can use empty spaces for drafting in pencil (but please remember to erase it before handing it in)

6 points you must include:

1. **Independent variable**
    a. List **min 5** different values of the independent variable
    E.g. 5 different concentrations with regular intervals apart/ 5 different temperatures
    b. State **how** you are going to set up these independent variables
    c. Remember to include the **apparatus** used
    E.g. simple or serial dilution / use a thermostatically-controlled water bath
    d. State how you make sure the experiment is **well-controlled / less error-prone**
    E.g. randomise sampling to avoid bias / make sure participants do not know which drug they are getting as results can be affected by subject expectation

2. **Dependent variable**
    a. This must be something that's **measurable**!
    E.g. rate is not measurable, rate is _____ over time
    You must state the variable that's measured to calculate the rate
    b. State **how** you are going to measure the dependent variables
    E.g. take a reading every 10 minutes
    c. Remember to include the **apparatus** used
    E.g. length is measured using a ruler / dry the plant in an oven until the mass becomes constant. measure dry mass using a weighing scale
    d. State how you make sure the experiment is **well-controlled / less error-prone**
    E.g. incubate enzyme and substrate separately, then start timer immediately after enzyme is added to substrate / use yeast without methylene blue as a colour standard
    e. State how you are going to **analyse the results**
    E.g. compare between group A and B / plot a graph / calculate using this formula

3. **Controlled variables**
    a. **Min 3** constant variables
    E.g. Temperature / pH / volume of solution
    b. State **how** you are going to keep these variables constant
    c. Remember to include the **apparatus** used
    E.g. use pH buffer/ use a thermostatically-controlled water bath

4. **Control**
    a. Control experiment ≠ controlled variable
    b. Control experiment is important to **ensure validity** of the experiment. To make sure that the independent variables are the ones causing the change in the dependent variable.
    c. Two types:
    Negative control = results should be always negative
    E.g. use boiled enzyme, so no rate of reaction
    Positive control = results should be always positive
    E.g. have petri dish without antibiotics for bacteria, bacteria will definitely grow

5. **Safety**
    a. State the **hazard** + **why it is dangerous** + **precaution**
    E.g. Strong acid – corrosive – wear gloves and goggles
    Enzymes / reagents – harmful– wear gloves and goggles
    UV light – mutagen – wear goggles
    Electrical appliances – danger of electrocution – wear rubber gloves / do not touch with wet hands
    (In field experiments) Pollen / insect bites – allergies – wear mask / protective clothing
    b. For human experiments, make sure they are aware of health risk, get consent before testing and allow test subjects to stop if they fell unwell.

6. **Repeat**
    a. Repeat experiment **at least 3 times and obtain a mean** to remove anomalies [R average]

List of common experiments:

- Simple and serial dilution
- Biological tests
- Enzyme experiments
- Potometer
- Respirometer
- Using redox indicators (DCPIP / methylene blue) to investigate the rate of respiration of yeast
- Using a gas syringe / photosynthometer to measure rate of photosynthesis in aquatic plants such as *Elodea*
- Chromatography to separate and identify chloroplast pigments
- Random sampling using frame quadrats
- Line or belt transects
- Mark-release-recapture technique
- Gel electrophoresis

Note: Some of these experiments have special procedures you have to remember!
The question can also describe to you an experiment you have never seen before and ask you to plan the experiment accordingly.

Dealing with Data (~8m)

Math skills Required

- Mean, $\overline{x}$
- Median
- Mode
- Range
- Interquartile range
- Ratio
- Percentage change = $\frac{\text{new} - \text{old}}{\text{old}} \times 100$
- Standard deviation, s = $\sqrt{\frac{\sum(x-\bar{x})^2}{(n-1)}}$
- Standard error, $S_M = \frac{s}{\sqrt{n}}$
- 95% confidence interval / error bars = mean ± 2 S_M
- Respiratory Quotient (RQ) = $\frac{[CO_2]}{[O_2]}$
- Rf value for chromatography = $\frac{\text{distance travelled with pigment}}{\text{distance travelled by solvent}}$
- Mark release-recapture method
  Estimated population size = $\frac{\text{no. of individuals in first sample x no. of individuals in second sample}}{\text{no. of individuals marked in second sample}}$
- Simpson's Index of Diversity
  $D = 1 - \left(\Sigma\left(\frac{n}{N}\right)^2\right)$
  where n = number of individuals of each species present in the sample
  N = the total number of all individuals of all species
- The Hardy-Weinberg equations:
  $p^2 + 2pq + q^2 = 1$
  $p + q = 1$

Note: Memorise all formulas stated here as they may not be provided in the exam!

Statistical Tests

1. Chi-squared test
2. t-test

→ To test for significance of difference between 2 data sets

3. Pearson's linear correlation
4. Spearman's rank correlation

→ To test for correlation

Null Hypothesis

There is no significant difference / relationship between _____ and _____.

Test	Chi-squared test, χ^2	t-test	Pearson's linear correlation	Spearman's rank correlation
Purpose	To show if the observed results are significantly different from the expected results	To test whether data from 2 samples are significantly different	To test for correlation between 2 paired sets of data	To test for correlation between 2 paired sets of data
Requirements	• **Discrete** / nominal data • Discontinuous distribution • Usually to test the results of: - Breeding experiments - Ecological sampling	• **Continuous** / interval data • Data is normally distributed • Standard deviations are approx. the same • Two samples have <30 values each	• **Continuous** / interval data • Both sets of data are normally distributed • Scatter graph indicates a linear / skewed relationship with no obvious outliers • There are 5 or more pairs of data	• Data is **discrete** / nominal • Discontinuous distribution • Scatter graph shows that there is a relationship (not necessarily linear / skewed) • There are 5 or more pairs of data • Data points within samples are independent • All individuals must be selected at random from a population
Formula	$\chi^2 = \sum \frac{(O-E)^2}{E}$	$t = \frac{\lvert \bar{x}_1 - \bar{x}_2 \rvert}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$	$r = \frac{\sum xy - n\bar{x}\bar{y}}{(n-1)s_x s_y}$	$r_s = 1 - \left(\frac{6 \times \sum D^2}{n^3 - n}\right)$ (D = difference in rank)
Degree of freedom	$v = c - 1$ (c = number of classes)	$v = (n_1 - 1) + (n_2 - 1)$	$v = n - 2$ (Either n or df can be shown in table!)	$v = n - 2$ (Either n or df can be shown in table!)
Analysis	If χ^2 / t value is **more than** critical value at p = 0.05 • The two data sets are **significantly different** • Probability of the difference occurring by chance is less than 5% • The null hypothesis is rejected • The differences are not due to random error / chance		If r / r_s value is **more than** critical value at p = 0.05 • The two data sets are **significantly correlated** • Probability of the relationship occurring by chance is less than 5% • The null hypothesis is rejected • The relationship are not due to random error / chance	

Note: Formulas for statistics test are provided.
However, you will need to memorise how to calculate degree of freedom for each test!

Evaluation of Data (~4m)

- **Always read the question carefully!**
  Describe = state your observations
  Explain = explain why the observations are as such
  Compare / contrast = tell me the similarities or differences between 2 sets of data

- **Always read the x and y axis first!**
  x-axis = independent variable
  y-axis = dependent variable

How to describe a graph:

1. **General trend**
   a. First, describe how the independent variable and dependent variable changes **overall**
      E.g. when x increases, y increases, but tails off when x increases above 10
   b. Then, if needed, split the graph into several parts to describe and explain separately

2. **Comparative data quote**
   a. Compare 2 points to support your statement
   b. Provide the x and y coordinates with the correct units
   c. You can also quote the maximum and minimum values where appropriate
   d. You can include some manipulative figures
      E.g. the number of cases reduced by half in 2010 compared to 2008

How to describe the data / table when there are multiple groups present in tables or graph:

1. **General trend**
   a. Look for similarities and make general statements overall
      E.g. Both increase as x increases.

2. **Comparative data quote**

3. **Compare within the group**
   a. Does it increase / decrease as independent variable increases?

4. **Compare between groups**
   a. Compare the end points
   b. Compare the max / min points
   c. Compare the range
   d. Compare steepness of the graphs

Conclusions (~3m)

- Based on observation of data given